



FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

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**EXTREMA: A PORTABLE ASSESSMENT OF ASTHMA
SYMPTOMS DUE TO EXTREME CLIMATE CHANGE.**

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ABSTRACT

This thesis work focuses on developing an intelligent mobile application that presents and highlights the health effects of climate change on asthma patients. The Android mobile application 'EXTREMA' is targeted towards patients in various scenarios, e.g., health, lifestyle, and education. The 'EXTREMA' application receives input from a patient along with smart weather sensor and the GPS (Global Positioning System) location sensor in the smartphone and communicates over the Internet with a remote server (Aware) accessible by research professionals who are in charge of the remote monitoring of the patients.

This thesis outlines the design, implementation, and evaluation via the deployment of a system aimed to help both individual users and researchers to efficiently gather self-reported symptoms data, and medication record according to weather conditions and user location. For gathering the data, there was no direct interaction with the users (asthma patients). However, during and after the development, the final version of the application was tested and evaluated during the thesis. Different measures were taken regarding the performance of the application, such as data loading, number of users, efficiency and accuracy of the weather sensor data.

The major output of the thesis is the application system, which can be used, by users and researchers to record medication and symptoms data in a meaningful format for future use. Hence, the main contribution is also towards improving the health of asthma patients and conducting research in the area.

Keywords: GPS, UI, application, RAW, URL, UUID, RSSI, mHealth

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FOREWORD

The thesis work is following the research under the Center for Environmental and Respiratory Health Research (CERH) in the field of mobile health (mHealth) and tracking the climate change effects on asthma patients.

I am thankful to my supervisor Dr. Denzil Teixeira Ferreira. I took a mobile and social computing course with him. I was interested in mobile computing and particularly in mobile application development. My interest was about the interconnectivity of smart technologies. During the thesis, I worked on smart sensors and mobile application. Dr. Denzil Teixeira Ferreira is dedicated and busy research professional. Instead of his busy schedule, he helped me in development, tutoring, guidance, and motivation throughout the project and my thesis work.

I am thankful to Dr. Timo Ojala, (Director, Center for Ubiquitous Computing) for giving me the opportunity to study and work in Finland.

I am thankful to my brother Dr. Ijaz Ahmad. He is an inspiration to our family. He motivated me throughout my education and helped me in every aspect of life.

Finally, I am thankful to my parents and siblings for support, motivation, and prayers.

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ABBREVIATIONS

API	Application Program Interface
IDE	Integrated Development Environment
BLE	Bluetooth Low Energy
IoT	Internet-of-Things
JSON	JavaScript Object Notation
UI	User Interface
GPS	Global Positioning System
App	mobile application
URL	Uniform Resource Locator
UUID	Universally Unique Identifier
RSSI	Received signal strength indicator
COPD	Chronic obstructive pulmonary disease
mHealth	mobile health
WHO	World health organization
CERH	Center for Environmental and Respiratory Health Research

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1. INTRODUCTION

The advances in technology and smart devices have a diverse impact on human life. These technological developments have brought improvements in human lives, ranging from medical therapies to recreational activities, and have thus a huge influence in many fields. The interconnectivity of smart devices further enhances life quality through gathering and sharing data. The Internet-of-Things (IoT) [1] concept made it possible to connect different technologies and integrate these technologies into daily life activities. Mobile and wearable devices have the potential to increase the opportunities for monitoring and collecting data accurately in real-time [2], [3]. Different sensors are available such as motion sensors, position sensors, and environment monitoring sensors, etc., for detecting respective data in real time. Smartphones are developed with technologies to connect to external sensors [5] through wireless communication media such as Bluetooth and near field communication (NFC) [4], which makes it possible to use a smartphone to collect motion, position, and environmental data. Mobile applications are used to collect and display information from these built-in sensors [41] and external sensors.

This thesis further bridges the gap between technological advancement and human health by making a mobile application as a tool to monitor the effect of climate change on Asthma patients. The thesis work is following the research carried out in the Center for Environmental and Respiratory Health Research (CERH) [6] in the field of mHealth and tracking the climate change effects on asthma patients. The CERH at the University of Oulu consists of a multidisciplinary group of researchers with a background in various departments such as the Institute of Health Sciences, Respiratory Medicine Unit and Institute of Clinical Medicine [6]. The strategy of CERH is related to research, education and outreach activities related to the effects of global environmental health effects.

Scientific research, carried out for a long period of time, has reached a conclusion that the effect of climate change has a wide range of impacts on human health. There are several different ways and factors that can affect normal human health due to the changing climate. Extreme variable temperatures in different parts of our planet have resulted in warmer weathers, heat waves, flooding, and droughts. Change in temperature and humidity have influence and effects on diseases such as diarrheal diseases, malaria, and other chronic diseases. The frequency of respiratory diseases especially asthma is high and increasing worldwide because of vulnerability due to climate change [20]. Hundreds of millions of people of all ages suffer from chronic respiratory diseases, which include asthma and allergies [21]. The hot and humid air found during summer is known to trigger asthma attacks [22], whereas asthma patients are more sensitive to health-related consequences of climate change [23]. The asthma attacks have been linked to both low and high atmospheric pressure [24]. Furthermore, there are many attributes of climate change (pollen, spores, pollutants, and air quality) that causes effects on asthma patients in different ways [25].

The purpose of the thesis work is to develop a mobile application that can track and monitor the health effects of climate change on asthma patients. The system is aimed to help both individual users and researchers to efficiently gather self-reported symptom data, and medication record according to weather conditions and user location.

The name of the mobile application presented in the thesis work is 'EXTREMA'. The 'EXTREMA' application is an intelligent mobile application that collects asthma patient's data and communicates over the Internet with a remote server, called Aware framework [38]. The Android mobile application 'EXTREMA' is targeted towards patients in various scenarios, e.g., indoor and outdoor activities. The 'EXTREMA' application receives input from a patient including daily medication and symptoms

feedback along with smart weather sensor and the GPS (Global Positioning System) location sensor in the smartphone. The daily notification system built in the application reminds the patient medication intake and symptoms feedback. The patient data is stored in the smartphone to be sent to the online server. The collected data is communicated over the Internet to a remote server, i.e., Aware server [38]. The data is accessible by researchers and professionals who are in charge of remote monitoring of the patients.

The application is developed with the most important features and can be extended with new features. The application is developed on the basic principles of effectiveness, efficiency, and satisfaction in a specified context of use [7], [33]. The user interface of the application is kept simple to achieve the maximum goal of collecting patient's data easily. The user interface of the application is evaluated empirically [34] using traditional usability methods and heuristics [8], [9]. The components of the application are tested, and each component response is working according to the functionality such as displaying sensor data, getting location data, saving medication record, symptoms feedback and communication of user data over the Internet to a remote server (Aware [38]).

2. RELATED WORK

The advances in technology and smart devices align well with the developing interests of human to integrate these technologies into their health care. The aim of using mobile technology in the health sector is to improve the quality of health care and monitoring [10]. One of the main goals of using these smart technologies in the health sector is to improve the quality and access to health care in real time. There are many factors in which mobile health can contribute to the wellbeing, and address health issues in an effective and efficient way. In 2017, a survey conducted in the United States shows that among 4000 adults 24 % use wearable devices to track their daily health practices [11]. It is estimated that since 2016 more than 250,000 applications are developed for personal health monitoring and 62% of the mobile phone users use their phone to access health-related information [12], [13], [14]. The smart device-based mHealth [12] interventions should focus on reliable data-driven applications to enhance and expand mHealth practices [13]. Mobile and wearable devices have the potential to increase the opportunities for health monitoring and collecting data accurately in real-time [2], [3]. Wearable devices passively monitor the health activities of users with effective engagements [3].

This thesis work is following the research in the field of mHealth and tracking the climate change effects on asthma patients. There are some solutions already available that track asthma patient's daily symptoms and medication records. The following section 2.1 discusses features of the existing/available solutions, to draw a contrast, and show the importance and novelty of this work.

2.1 Asthma tracking mHealth applications

There are several applications available related to Asthma and chronic obstructive pulmonary disease (COPD) on google play store. In this work, the applications with a maximum number of downloads and higher user's ratings are mentioned and discussed.

2.1.1 AsthmaMD

The AsthmaMD [15] application is tracking and managing Asthma and COPD. The application is tracking a patient's medication record and keeps Asthma diary. The peak flow meter is used to track the Asthma symptoms and the peak flow values are entered manually in application. A patient can select the medication from the existing list or enter manually. The reminder can be set up for daily medication intake. A patient can select the option of triggers such as dust, pollen, smoke, etc. to specify the symptoms of allergies. The peak flow values are visually displayed daily.

2.1.2 Asthma Tracker

Asthma Tracker [16] application is tracking peak flow values, medication intake and symptoms record. A reminder can be set up for daily medication intake and to measure the peak flow. An additional feature of this application is the integration of google fit API to count the user steps. The application displays the peak flow, puffs, user steps, and symptoms visually.

2.1.3 Peak Flow

Peak Flow [17] application saves daily peak expiratory flow readings and displays the weekly or monthly values visually. The application shows the peak values before and after the medication intake. The application has English and German language options.

2.1.4 Comparison

The following table shows the comparison of the previous mHealth monitoring Asthma solutions.

Table 1. Asthma tracking applications comparison.

Application	AsthmaMD	Asthma Tracker	Peak Flow
Peak flow value	X	X	X
Medication	X	X	X
Symptoms	X	X	
Location tracking	X		
Weather data			
Notifications	X	X	
Graphs	X		X

The existing solutions are targeted towards the symptoms and medication of asthma. Climate change and air pollution are one of the major concerns that trigger and affects Asthma and other chronic diseases. Therefore, an improved solution is needed to monitor and track the causes and effects of such chronic diseases in real time with respect to weather data.

2.2 Effects of climate change on Asthma Patients

The temperature on the Earth's surface has risen and is higher than the previous decades [18]. Research has been carried out for a long period of time that shows that the effect of climate change has a wide range of impacts on human health, directly and indirectly [19]. Human health is vulnerable to the surrounding environment. The frequency of respiratory diseases, especially asthma, is high and increasing worldwide because of vulnerability due to climate change [20]. Hundreds of millions of people of all ages suffer from chronic respiratory diseases, which include Asthma and respiratory allergies [21]. The hot and humid air found during summer is known to trigger asthma attacks [22], and asthma patients are more sensitive to health-related consequences of climate change [23]. The Asthma attacks have been linked to both low and high atmospheric pressure [24]. There are many attributes of climate change (pollen, spores, pollutants, and air quality) that causes effects on asthma patients in different ways [25]. The effects of climate change on the health of the people are the same either they spend time indoors or outdoors [19].

In a study of activity patterns presented in [26], it is observed that most of the time spent indoors is at homes, rather than other indoor places like offices, indoor gyms, and

swimming pools, etc. To be exact, 95.6 % of the participants stated that 66 % of their indoors time is spent at homes [26]. Therefore, the collection of data in indoor and outdoor environments is important for the purpose of this research. The main reason is that climate change has effects not only outdoors but also indoors, and the proper studies must be carried out to measure the effects on Asthma patients in indoor environments. Moreover, the previous solutions haven't targeted climate change and its effects on Asthma patients. Similarly, in the previous work, the patient's data is not available remotely to doctors and professional researchers. The data can be forwarded to doctors by exporting it manually. Secondly, the saved patient's data in user mobile can be risky and could be lost due to many reasons such as loss or damage to the phone. In this research, external sensors besides mobile devices are used to collect real-time data. In summary, more diverse attention is needed in different scenarios to collect long-term data of Asthma patients with respect to weather conditions [25], which is the main focus of this thesis.

2.3 Weather data sensor

There are two different ways to collect weather data. The traditional weather stations send weather data updates every 15 minutes based on user location. The limitation of the weather stations is that they send outdoor weather data. Whereas, the advantages of smart devices are that they can send context-specific data, both indoor and outdoor data on a need basis, and are capable to provide solutions to specific issues. The smart weather sensor Ruuvitag [27] is an open-source Bluetooth sensor, which is capable of sending weather temperature, air humidity, pressure, and motion information. The sensor collects weather data in real time and capable of sending weather data every single second for 24/7.

2.4 Ability to monitor user data remotely

The previous solutions track and monitor the patient's data in mobile phones of users. The user's data is displayed graphically in the user's mobile. The data can be forwarded to doctors by exporting it manually. The data stored in the user's mobile can be risky and could be lost due to many reasons, such as loss or breaking of mobile phones. Therefore, instead of tracking and monitoring the symptoms of asthma patients only in mobile, the user data should be available online to be monitored by experts remotely. The suggested system provides researchers and health professionals to monitor and access patients' data remotely. The format of the data is easily understandable and readable. The data format is JSON format [28], which provides a higher level of flexibility and efficiency [29].

2.5 Contribution of the thesis

The previous work is targeted towards the symptoms and medication of Asthma and chronic obstructive pulmonary disease (COPD) patients. Climate change and air pollution are one of the major concerns that trigger and affect Asthma and other chronic diseases. Therefore, an improved solution is suggested to monitor and track such chronic diseases in real time with respect to climate data.

The proposed solution, i.e., 'EXTREMA' application, is more towards the effects of climate change on Asthma patients. The weather data can be collected in real time indoor and outdoor based on user location. Furthermore, the proposed solution has the option of setting up the notification time for medication intake and symptoms feedback according to the user's preferences. Thus, the solution is mainly focusing on the usability factor, besides other health benefits.

Secondly, the weather data and user data are the main focus of the application. Therefore, it is necessary to collect weather data and user data and store it safely. The online database

is needed to save the user data. The Aware framework [38] is the proposed data server for the collected data. Instead of simply tracking and monitoring the symptoms of Asthma, the application will send the user data remotely to the online Aware server [38].

3. SYSTEM DESIGN AND IMPLEMENTATION

This chapter discusses the implementation and system design of the thesis work. The technical information about the system, including the system structure and software design decisions are taken. This section also covers the system architecture, activities, tools, use cases and UI components of the system. The thesis work is consisting of two main parts, which includes developing mobile application and collecting user's data based on geographical locations. The mobile application is, basically, focusing on the UI design, interaction of the user with the application and collecting user data as discussed in section 3.4. User data consists of daily medication records, symptoms, weather data, user location and number of satellites used by the user mobile, which indicates the user position and indoor and outdoor activities as discussed in section 3.5. Aware framework [38] is used to store user data online as a remote server, is discussed in section 3.3. The application is developed with English, Finnish and Greek language option. The application will automatically adopt the choice of the user mobile language option based on user location.

3.1 Architecture

The general architecture of the system in figure 1 shows the structure, flow and the components of the system, which includes user data, weather sensors data, local database to store user and sensor data and a remote server. Ruuvitag [27] sensors are connected to the mobile application through Bluetooth technology. The sensor data and user data (medication records, daily symptoms, location data) are saved in a mobile phone using an SQLite database. The collected data is communicated over the Internet to a remote server, i.e., Aware server [38]. The data is accessible by researchers and professionals who are in charge of remote monitoring of the patients. The following figure 1 shows system architecture.

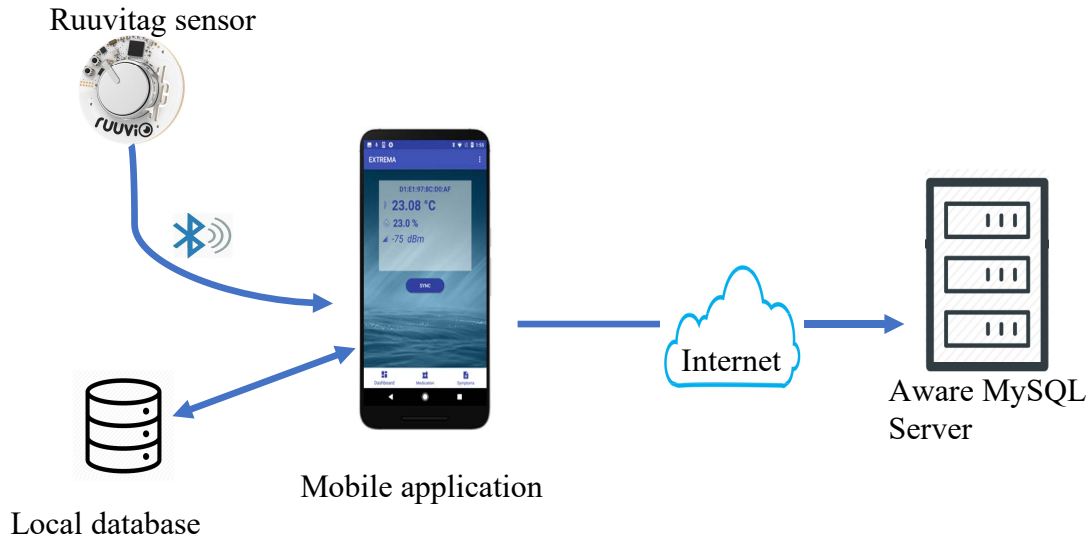


Figure 1: General system architecture.

3.2 Ruuvitag sensor

Ruuvitag [27] is an open-source Bluetooth sensor, which is capable of sensing temperature, humidity, pressure, and motion information. For the developers, it has RAW mode and URL mode. Ruuvitag [27] works as a proximity beacon using Eddystone [37] open beacon protocol. The sensor collects weather data in real time and capable of sending weather data every single second for 24/7. The advantage of Ruuvitag [27] sensor is the battery life, which is up to 3 years and instant temperature data updates. The following figure 2 shows the Ruuvitag sensor.



Figure 2. Ruuvitag Sensor.

3.3 Local database and server

The user input and Ruuvitag [27] sensor data are stored locally on user mobile using SQLite database. When the user has access to the Internet, the user data is then synced with the online Aware server [38]. The user data includes login information, registration data, daily medication records and feedback on symptoms. While the Ruuvitag sensor [27] data includes device ID, weather temperature, air humidity, and device RSSI. Additionally, user location latitude, longitude, and a number of satellites used to indicate the user positioning are saved as user data in user mobile phone. The application-specific generated user UUID is stored to identify the individual user and his medication history. The format of the patient's data is easy to understand and read. The data format is JSON format [28], which provides a higher level of flexibility and efficiency [29]. The following table 2 shows the format and detail of each collected data.

Table 2. User data format and details.

Device	<pre>{ "tableName": "Ruuvitag", "deviceId": "ba890ac9-55a3-416b-bd38-387ffeb8c42", "data": { "temperature": 22.99, "humidity": 23.5 "RSSI": -48 }, "timestamp": 1525266608 }</pre>
Medication	<pre>{ "tableName": "Medication", "UUID": "ba890ac9-55a3-416b-bd38-387ffeb8c42", "data": { "date": 1545256800000, </pre>

	<pre> "Drugs": "panadol", "Other_Drugs": "disprin", "New_Drugs": "panadol", "Asthma_Visits": "7", "Allergy_Visits": "10", "Other": "nil" }, "timestamp": 1525266608 } </pre>
symptoms	<pre> { "tableName": "Symptoms", "UUID": "ba890ac9-55a3-416b-bd38-387ffeb8c42", "Symptoms": "[{ "Shortness of breath": "Not at all", "Phlegm production": "Moderate", "Cough": "Mild", "Wheezing": "Strong", "Nocturnal wake ups caused by symptoms": "Once", "Opening medication of asthma (short-acting)": "Once", "Opening medication of asthma": "2-3 times", "Your own estimation about asthma balance": "Poorly under control" }, { "Did your asthma prevent you to act normally in work, school or home \ leisure time today?": "Yes", "Where are you now?": "Outdoor" }]", "timestamp": 1525266608 } </pre>
Location	<pre> { "tableName": "Location", "UUID": "07dbc89e-146c-4dcf-88c4-9c0645e9730f ", "data": { "Latitude": 12334374587, "Longitude": 812859647127, "Satellites used": 20 "isIndoor": False }, "timestamp": 1545377870217 } </pre>
Participant	<pre> { "tableName": "Participant", "UUID": "07dbc89e-146c-4dcf-88c4-9c0645e9730f ", "data": { "Name": "murad", "DateOfBirth": "12-7-1900 ", "Email": "muradahmad08@gmail.com", "Password": "murad", "Uuid": "07dbc89e-146c-4dcf-88c4-9c0645e9730f" }, "Timestamp": 1545069842641 } </pre>

3.4 User interface

The application is developed with user experience and usability basic principles of effectiveness, efficiency, and satisfaction [33]. The user interface of the application is kept simple to achieve the maximum goal of collecting patient's data. The mobile application is designed simple, attractive and easy to use; therefore, the user interface went through several iterations discussed in section 3.4.2. Each user input and functionality for a specific task is described in a use case scenario in the next section 3.4.1.

3.4.1 Use cases

The sequences of interactions between the system and the users are described in the following general use case diagram. Each functionality of the application presented in figure 3 shows the task users can perform while interacting with the 'EXTREMA' application.

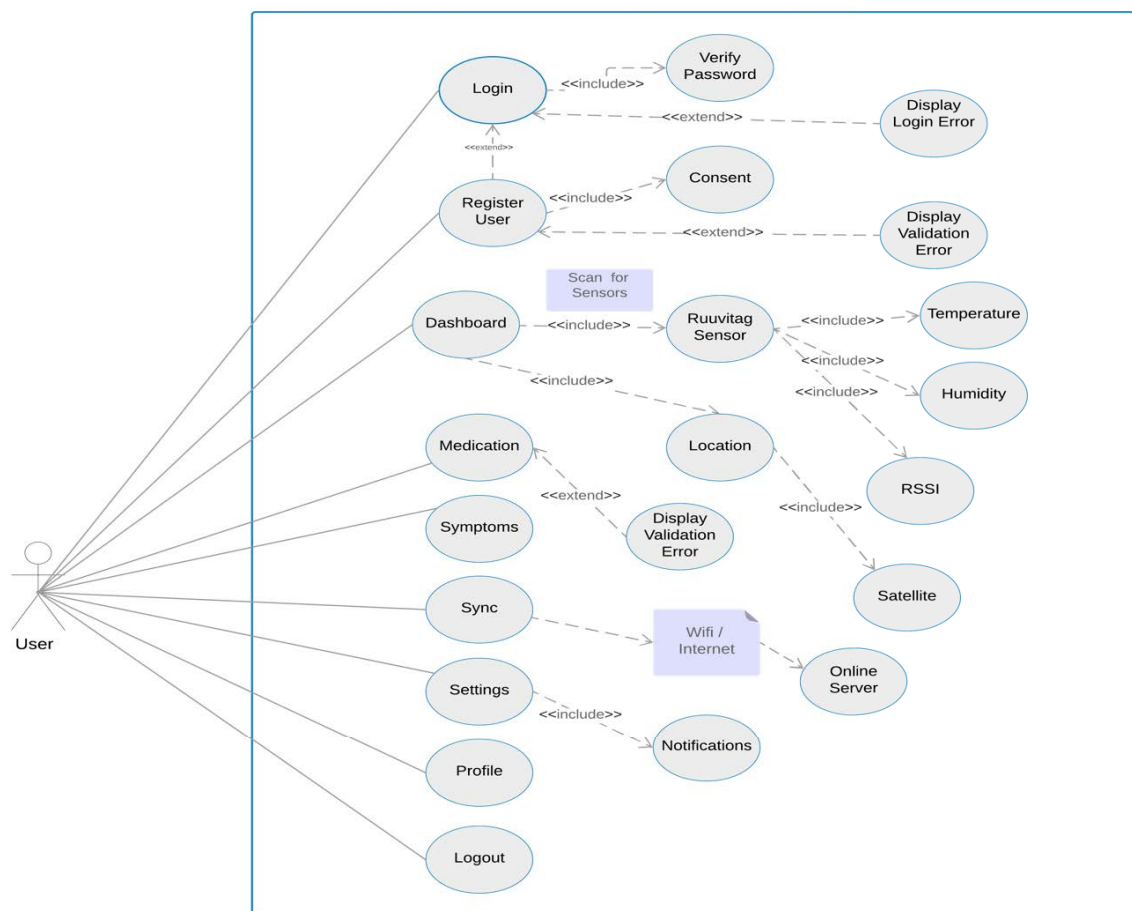


Figure 3. Use case diagram of 'EXTREMA' application.

The use cases were generated based on the requirements such as login, registration, user daily medication records, symptoms feedback, and daily notifications, etc. and interaction between the user and 'EXTREMA' application. Each use case explains the flow of interactions and describes functionality in the application. The code inside each block is explained in more detail in section 3.5 – Implementation.

After installing the application, the user requires to register and accept the consent form. Once the user registers, he gets a UUID, which is used to identify and distinguish him

from other users. The following figure 4 shows the registration and login activity of the application.

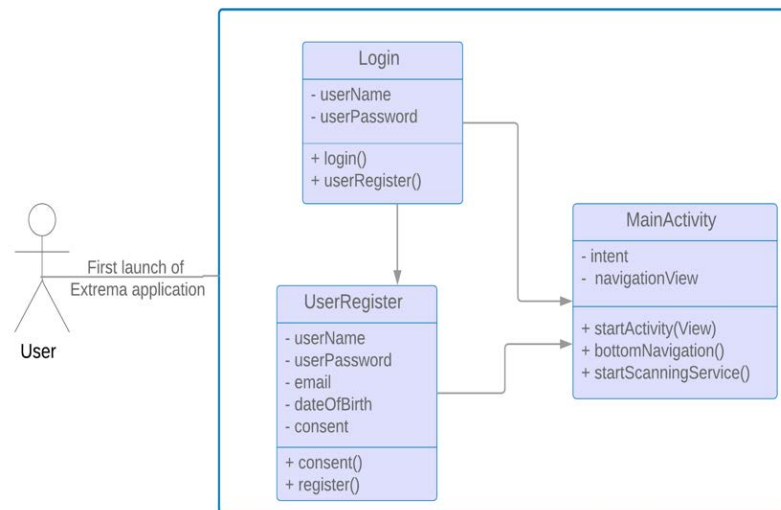


Figure 4: Use Case – First launch of application.

After the registration or login, the user is redirected to the main dashboard. The application starts scanning in the background for the Ruuvitag [27] sensors and user current location. The application displays sensor data includes weather temperature, air humidity, RSSI and device ID on the dashboard screen. The sensor data on the screen is updated continuously. The user daily medication records and symptoms feedback, location data and sensor data are saved in the local database. This functionality of the SYNC buttons on the main screen is to send the user data (medication record, symptoms feedback, location data, and sensor data) to the online Aware [38] server. The following figure 5 shows the main activities of application.

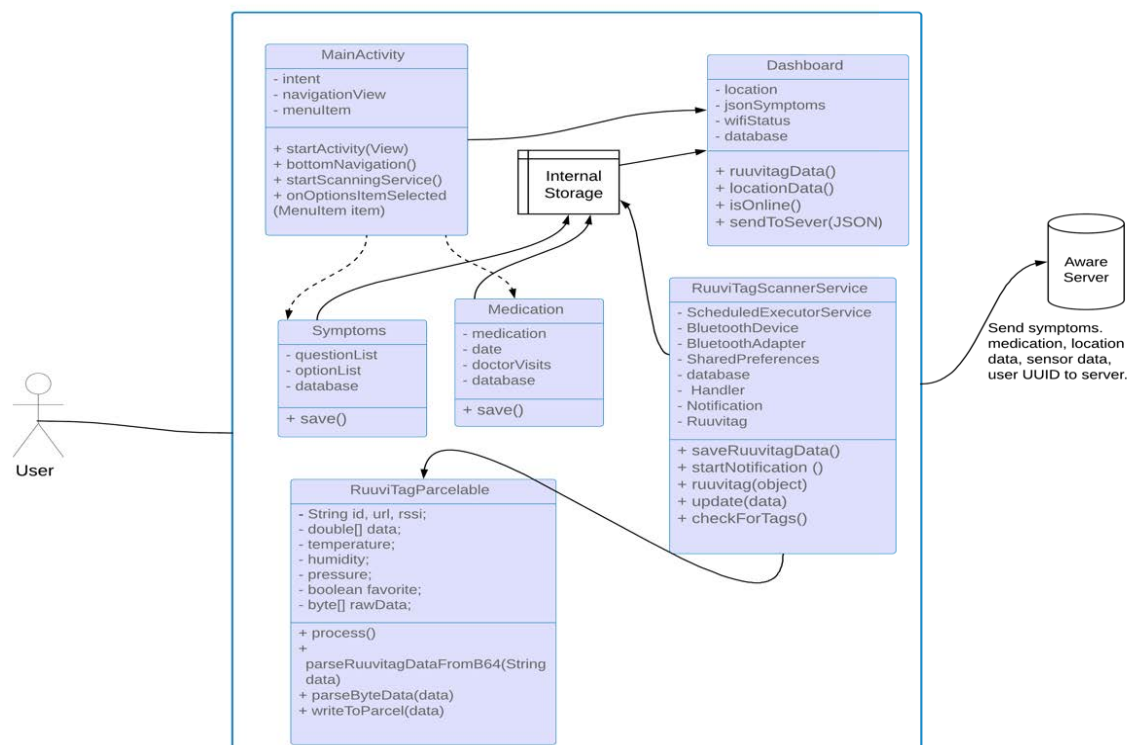


Figure 5: Use Case – Main activities in application.

The application has a notification system. The notification system reminds a user of daily medication intake and symptoms feedback. The users can save preferred notification timing from settings. The user can save morning and evening notification time as shown in the following use case figure 6.

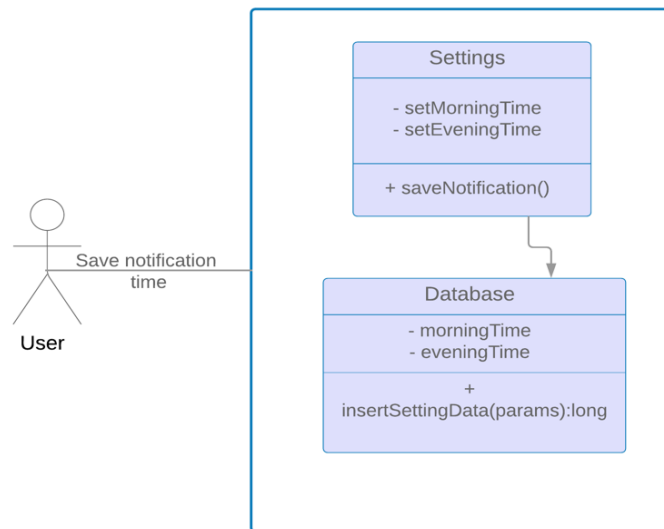
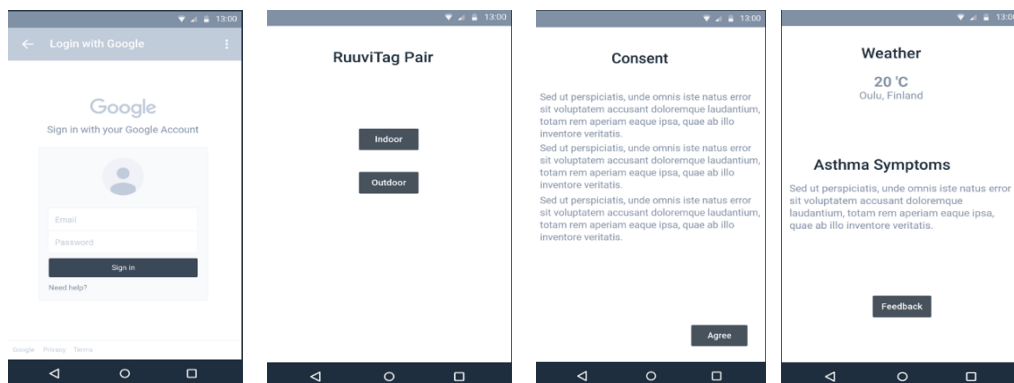


Figure 6: Use Case – Settings and saving notifications time.

3.4.2 Design Iterations

Mobile application development follows the iterative development process. Each component of the application is tested visually and compare with the requirements of the application. Every user interface element went through several phases of designing and development.

The following figure 8 shows the mockups and initial understanding of the application after a brief discussion about the project. The application will have a user login screen, consent form, sensor data screen, and symptoms.



a) Login screen

b) Sensor pairing

c) consent form

d) main screen

Figure 8. Initial mockup of application.

Figure 8 shows the low-fidelity mockups of the application. During the mobile app development cycle, the user interface design went through many iterations with respect to the mockup design and requirements [39]. As the application evolved and the tasks were completed the design was adapted according to requirements of the application. The following figure 9 shows the initial design of the application.

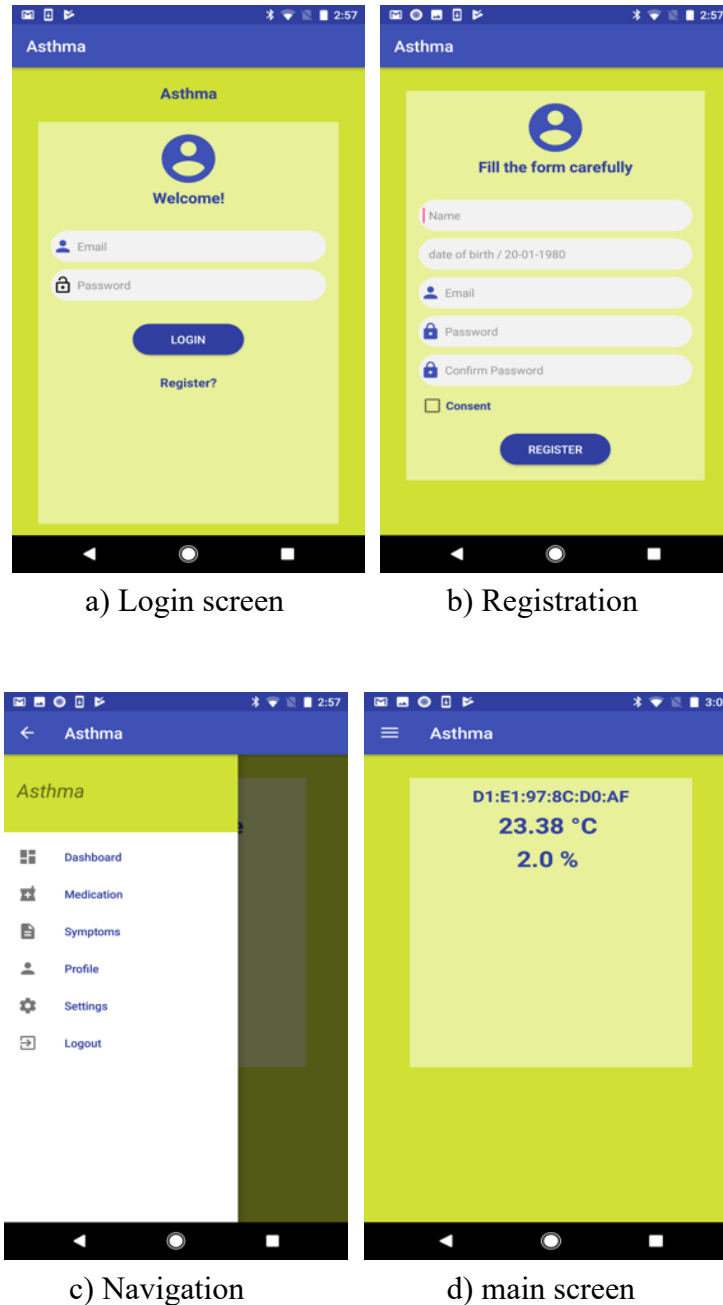
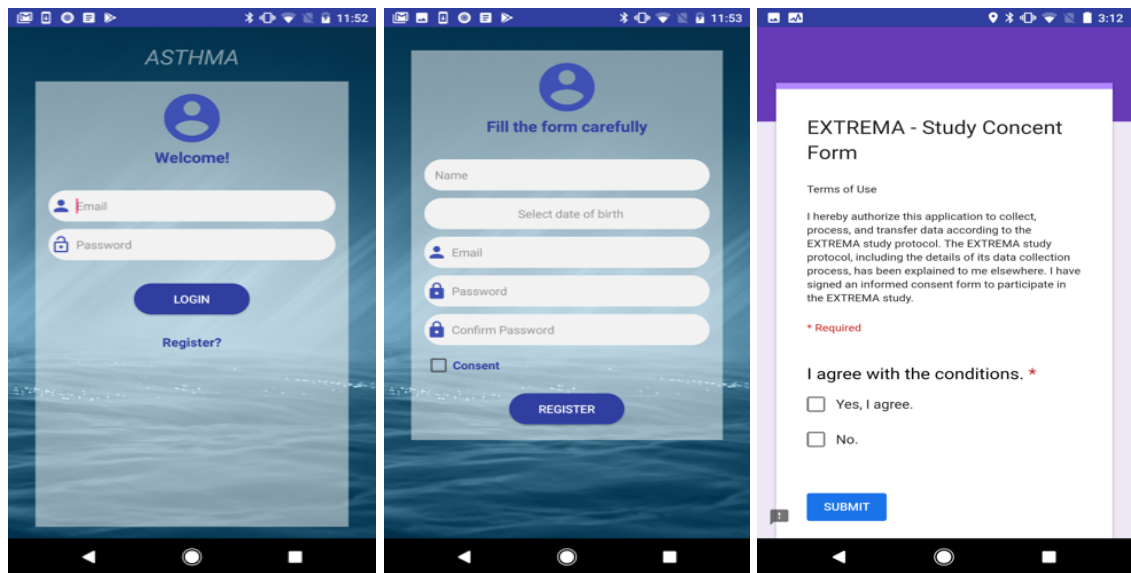


Figure 9. Initial UI of application.

The screens in figure 9 (a) show the login screen of the application. If the user does not have an account, he/she will click the register text and will be directed to the registration screen in figure 9 (b). For the registration, the user needs to enter the necessary information and read the consent form. The user will be registered after filling the form. The screens in figure 9 (c) show the navigation drawer which includes dashboard tab,

medication tab, symptoms tab, user profile tab, settings tab and log out tab along with the respective icons. Figure 9 (d) shows the main screen, which displays the sensor data that includes the device ID, weather temperature and air humidity. This was the initial design of the application.

Since the process of designing and development of mobile applications is iterative, thus after a few iterations with respect to the requirements and expert's views on each screen design the final version of the application is released with the improved look and feels as shown in the following figures.



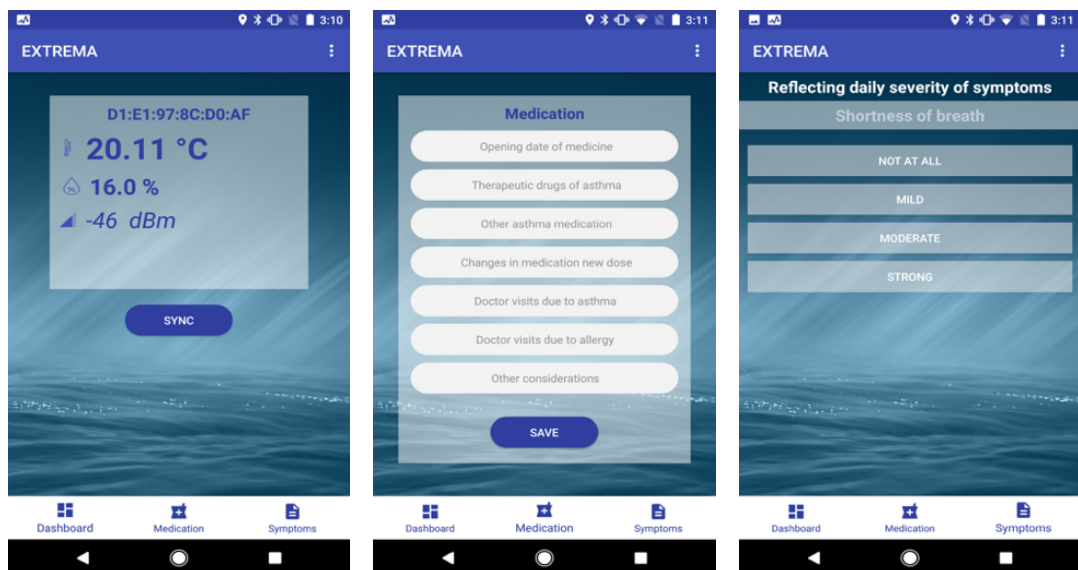
a) Login screen

b) Registration

c) Consent form

Figure 10. UI: Login, Register, Consent form screen.

The above figure 10 (a) shows the login screen. User can register by clicking the register text in the login screen. Figure 10 (b) shows the registration screen. The information on the registration screen must be entered. Each text field is mandatory. The empty text field displays the error text. Figure 10 (c) is the consent form.



a)

b)

c)

Figure 11. UI: a) Dashboard, b) Medication, c) Symptoms screen.

The dashboard screen in the above figure 11 (a) shows device ID, weather temperature, air humidity, and signal strength along with the respective icons. The SYNC button on the dashboard screen refreshes the data and checks the availability of the Internet. With Internet availability, it sends the user data which includes medication records, symptoms record, user location data, and sensor data to an online server (Aware). The screen in figure 11 (b) shows medication record which includes the date of medication, therapeutic drugs of asthma, other asthma drugs, new medication or changes in drugs, doctor visits due to asthma, doctor visits due to allergy and any other considerations. If there is the Internet, the medication data is sent to the online server (Aware) otherwise it is stored in a local database in the user mobile. If the user presses the SYNC button on the dashboard, the data is sent to the online server. The screen in figure 11 (c) shows the symptoms screen with one of the questions asked from the user. The symptoms screen has many questions prepared by the doctors. Each question has multiple-choice options. The user can select any option according to daily feedback on asthma symptoms. Finally, the navigation drawer is changed to bottom navigation as shown in the following figure 12.

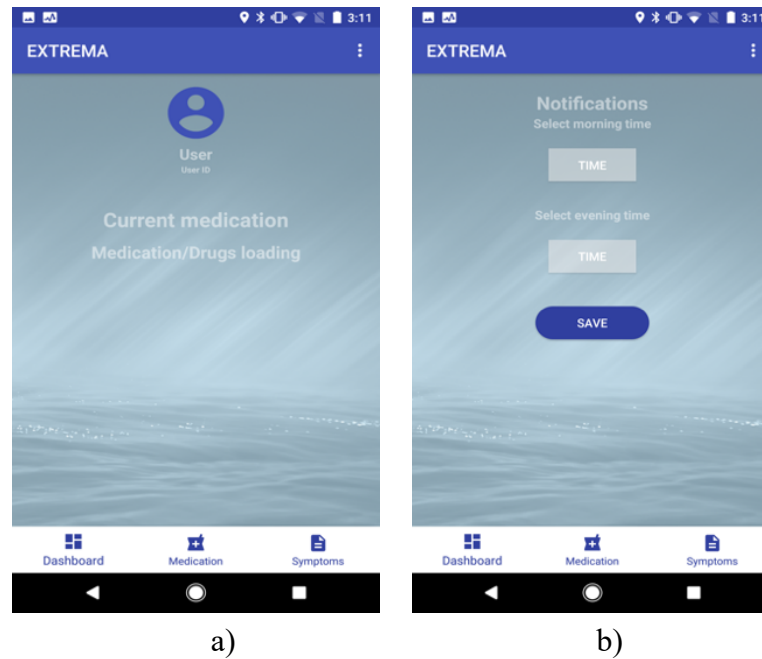


Figure 12. UI: a) User profile, b) Settings screen.

The user profile screen in the above figure 12 (a) shows the user name, user ID and the user medication record. The settings screen in figure 12 (b) shows the notifications setting along with the time buttons. After clicking the time buttons, the user can set time for daily medication and symptoms feedback which will allow the user to get a notification on the desired time.

3.5 Implementation

This section describes the process of development, tools, and equipment, programming language and methodologies used for this mobile application during development. The main task of the application includes feedback on daily symptoms and medication record along with the weather data to see the climate change effects on the user's daily life

routine. The mobile application is developed with three languages options, i.e. Greek, Finnish, and English. The information is automatically translated into one of these languages based on the user location and mobile language settings.

3.5.1 Tools and technology

Android Studio is used for the development of the mobile application as a platform. Android mobile Google Pixel is used to test the software during the designing and development. Java programming language is used for development as an android programming. The system was developed on Android version 8.0.0. The compile SDK version was 28 and the minimum SDK version was 19 along with some libraries including android-beacon, Bluetooth, Gson, Aware and volley. Ruuvitag [27] sensor is used for sensing relative air humidity and weather temperature. Sqlite3 is used to store the sensor data, location data, medication record, symptoms data, and user information locally on the mobile device. Aware framework [38] is used to store user data online as a server.

3.5.2 Application

After installing the application on a mobile device, the user needs to get register to the application. If the user is already registered and is a returning user, then he/she will be redirected to the login screen. After entering the credentials on the login screen, the user will be redirected to the main screen in which the user will see the sensor data. The sensor data includes device ID, weather temperature, air humidity, sensor signal strength. The SYNC button on the main screen is for synchronizing user data with online Aware server. The main screen has the bottom navigation that includes the Medication, Symptoms and Dashboard screen tabs. The main screen has the setting option on the top right corner. The setting option has a user profile, notifications settings, and log out tab.

3.5.3 Dashboard

The dashboard screen shows device ID, weather temperature, air humidity, and signal strength. The SYNC button on the dashboard screen refresh the data and check if there is Internet connectivity it sends user data to the online aware server. The user data includes medication record, symptoms record, user location data, and sensor data. The dashboard screen has the bottom navigation, which includes the dashboard tab, medication tab, and symptoms tab. Furthermore, the screen has the setting option through which the user can set notifications for symptoms and medication records, as well as a logout tab, form the application. The following figure 13 shows the dashboard or main screen of the application.

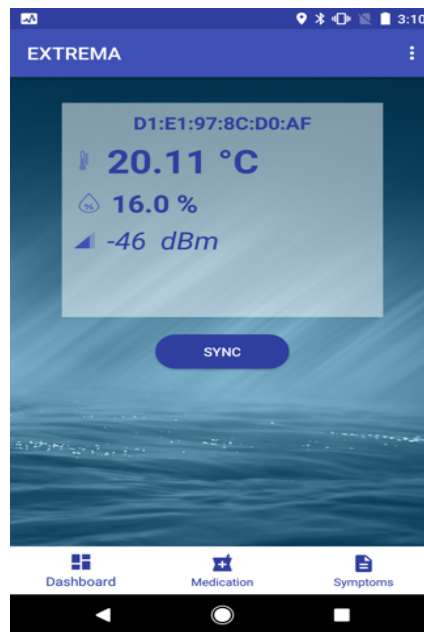


Figure 13. Main screen or the dashboard of the application.

3.5.4 Medication

The medication screen shows medication record that includes the date of medication, therapeutic drugs of asthma, other asthma drugs, new medication or changes in drugs, doctor visits due to asthma, doctor visits due to allergy and any other considerations. When the user clicks the save button if the mobile has access to the Internet the medication data is sent to the online server otherwise it is stored in a local database in the user mobile. The SYNC button on the dashboard screen, send the user data to the online Aware server. The following figure 14 shows the medication screen.

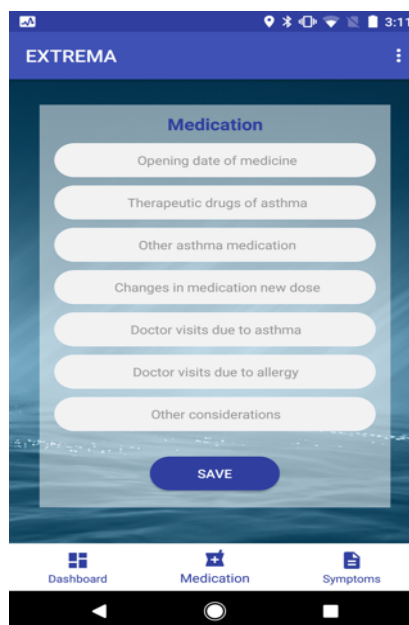


Figure 14. The medication screen of the application.

3.5.5 Symptoms

The symptoms screen displays questions regarding asthma symptoms along with the multiple-choice option. The symptoms screen has the following questions prepared by the doctors with multiple options.

Table 3. Daily severity of symptoms.

<i>Reflecting daily severity of symptoms</i>	
Questions	Answer
Shortness of breath	a) Not at all, b) Moderate, c) Mild, d) Strong
Phlegm production	a) Not at all, b) Moderate, c) Mild, d) Strong
Cough	a) Not at all, b) Moderate, c) Mild, d) Strong
Wheezing	a) Not at all, b) Moderate, c) Mild, d) Strong
Nocturnal wakeups caused by symptoms.	a) Once, b) 2-3 times, c) 4 or more times
Opening medication of asthma (short-acting)	a) Once, b) 2-3 times, c) 4 or more times
Opening medication of asthma	a) Once, b) 2-3 times, c) 4 or more times
Your own estimation about asthma balance	a) Good, b) Poorly under control, c) More or less under control, d) Not at all under control
Did your asthma prevent you to act normally in work, school or home \ leisure time today?	a) Yes, b) No
Where are you now?	a) Outdoor, b) indoor

The presentation of the symptoms on a mobile screen is shown in the following figure 15.

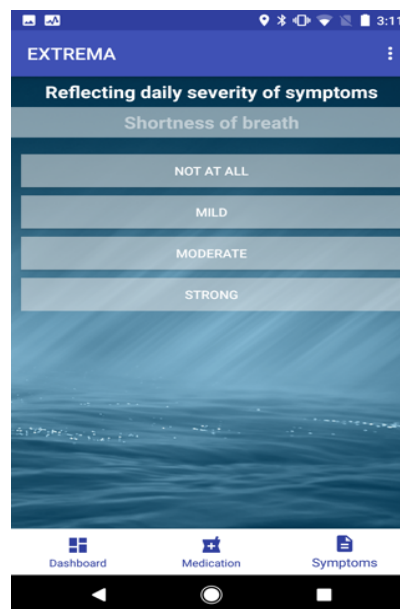


Figure 15. The symptoms screen of the application.

3.5.6 Notifications

A notification system is implemented for the purpose of informing the user if there are actions such as medication record and symptoms feedback that they should take to ensure the daily routine of the asthma patient. When the user clicks options at the top right corner, a small option list appears. As the user clicks the settings tab, the user is redirected to the notification setting screen. The setting screen has two 'Time' buttons, one for setting morning notification time and the other for the evening notification time. The user can set time for daily medication and symptoms feedback, which will allow the user to get a notification popup on the desired time. The following figure 16 shows the notification setting process.

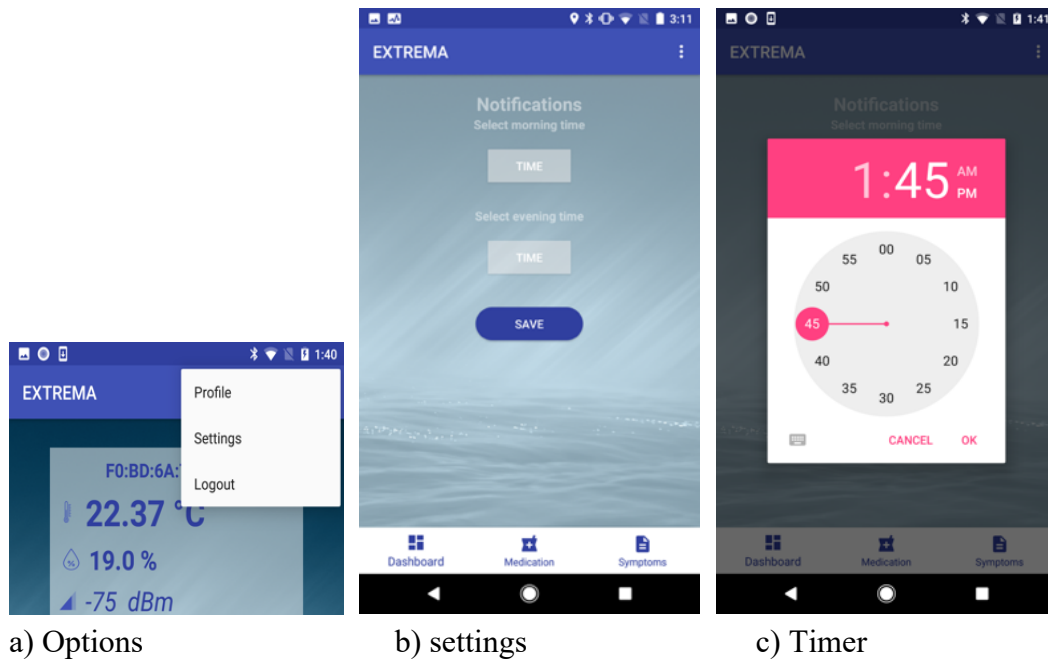


Figure 16. The notifications settings screen of the application.

The following figure 17 shows the notification popups on desired time during the day.

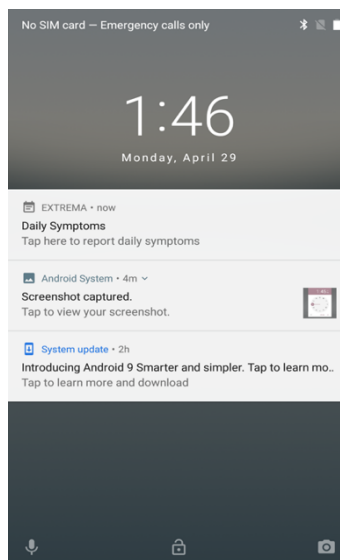


Figure 17. Notifications popups of the application.

3.5.7 Classes

The main functionalities of the ‘EXTREMA’ application are user location, Ruuvitag [27] sensor data, user information and credentials, medication record, symptoms feedback and settings, which include daily notifications popups. Each functionality has a separate class and methods. These classes and methods follow purely object-oriented programming concepts and methodologies for each task and sub-tasks. Furthermore, there is one service class, i.e., ‘RuuvitagScanner’, which is running in the background to search for the Ruuvitag sensors and connect the sensor to the mobile device and get weather data from the sensor through Bluetooth. The sensor data is read in bytes, which is decoded using ‘base64’ class.

‘Ruuvitag’ class is the main class in which sensor data which including air humidity, temperature and pressure are converted from bytes to strings to get human readable and understandable data after necessary calculations and algorithms. Finally, the sensor data in a readable format is stored in the local database. The ‘RuuvitagScanner’ class read data from the sensor every minute to get the updated and latest data. The user location is traced to see the user location, activities such as indoor or outdoor and measure the effects of climate change effects on users. The user gets notification two times during the day as morning and evening according to the user preferences to send the symptoms feedback and medication record to online Aware server. The classes for each functionality in the application are shown in the following table 4.

Table 4. Main classes used during the development of the application.

Main Classes	
App	This class includes the login and notification channel ids. When the application launches this class is the first running class of the application.
Consent	This class has the Webview to display the consent form.
DBModel	This class has the sensor data and signature methods to get data from the local database.
Dashboard	This is the main display screen class. This class gets data from the local database to display. This class has a SYNC button to send the user information, device data, medication data, symptoms feedback, location data to the online aware server.
Database	This is the local database class. It saves all the application data including user login, registration data, sensor device data, medication data, symptoms feedback, location data into a local mobile device.
Feedback	This class has symptoms questions with two choice options.
Foreground	This class manages the sensor and its states in the foreground and background.
Login	This class has the login credentials to check if the user has account or not.
MainActivity	This is the main activity of the application which redirects the classes and screens.

Medication	This class display medication data and save medication data in the database.
NotificationReceiver	This class has a receiver service for notification initiation.
QuestionLibrary	This class has symptoms questions and answers choice options.
RuuviTag	This class has the main conversion of sensor data from bytes to strings and has signature methods for sensor data.
RuuviTagScanner	This is a service class to search for Ruuvitag sensors in the background and get data from sensors. This class also has user notification time initiation and calling notification receiver class.
Settings	This class has notification time settings and save notification time in the database.
Symptoms	This class support user interface of the symptoms questions and is responsible for symptoms data. it also saves data in the database.
UserProfile	This class user profile data such as user name, user ID, medication record.
UserRegister	This class has user registration data.

The colors used in the user interface buttons, text and icons for the application are stored in a separate directory in colors XML file. The text for the whole application such as buttons names and text are stored in the String XML file. These files are in the values folder inside the res folder. The buttons design, the shape of the buttons and icons which reflect screen effects are stored in the drawable folder. The drawable folder includes XML files for each effect and design. The screen design files are in the layout folder that includes all screens layouts.

4. RESULTS

This chapter discusses the results of the thesis work. The technical information and results conducted during the evaluation and testing of the application in the real world are collected and presented. This chapter covers the User Interface (UI) evaluation in section 4.1 that includes heuristics of UI components of the system. The usability tests and results are presented in section 4.2. The validation of sensor data is discussed in section 4.3. The server data confirmation is presented in section 4.4. The performance testing of each major component of the application is discussed under section 4.5. The application is automatically translated to these three languages Greek, Finish and English based on location and mobile phone language are discussed under section 4.6.

4.1 User interface evaluation

The main focus of the user interface evaluation is to get the feedback of users on the look and feel of the system, as well as the user interaction with the design of the application. The goal of the application is to provide a simple and attractive user interface to a user for attempting to perform specific tasks and actions. The purpose of the user interface evaluation [40] was to find out whether the information is presented in an understandable way, and that a typical user can understand the intended core task. The aim, and thus, the methodology used in this section is that the interface of the application should be easy and simple.

Empirical evaluation [34] is conducted during the project work. The user interface of the application is evaluated using usability methods and heuristics [8]. [9]. The evaluation was conducted in the University of Oulu, Finland, and its surrounding campus area by interacting with the participants directly. The total number of participants was 25. The application was presented to the participants, and they were briefed about the purpose of the application. The participants used the application, and after testing the application, they were given a survey in printed forms to fill the user interface heuristics. The survey was designed to be simple and easily understandable while maintaining the usefulness of the information to be gathered. The user was given a choice to select one of the three options, i.e., poor, satisfactory and good. The response of the individuals is presented in the following figure 18.

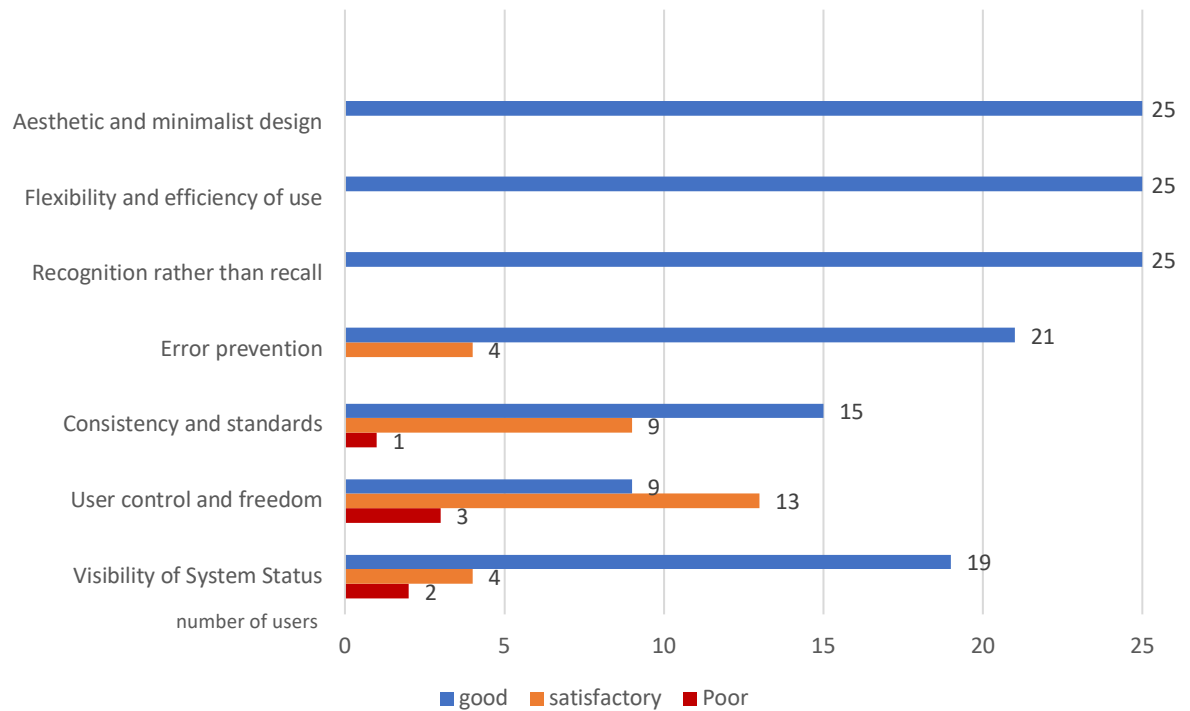


Figure 18. UI evaluation participant's response.

The above figure 17 shows that the aesthetic and minimalist design of the application is quite appreciated and 25 participants marked it good and the response was the information presented on screen is simple and understandable. Similarly, the flexibility and efficiency of use are also appreciated and marked good by all of the 25 participants. The response of the participants was that the interaction with the symptoms screen is in a sequence, easy and fast. The overall application is designed with the simple user interface so that after the first interaction, it becomes obvious to all users. The recognition is appreciated and marked good by all participants. Four users marked error prevention to be satisfactory. Their observations were about the medication screen that it is difficult for a user to fill the form manually each time. Consistency and standards attributes of the application are marked poor by one user and his observations were about the navigation drawer. He mentioned that the left navigation drawer is standard in such applications to keep user symptoms and medication tab hidden. Three participants marked user control and freedom to be poor. Their observations were about symptoms screen undo action related to answering feedbacks on the screen. Two participants marked the visibility of the system status to be poor. Their observations were about getting the summary of the symptoms and medication record after feedback.

The participants were asked generally about the application and their view about buttons size, color, text alignment, and the response was good. The following table 5 shows the general views of the application and number of users to reflect on the appearance of buttons and text of the application.

Table 5. UI buttons and text discussion results.

Number of users	Buttons size, color, and alignment		UI text	
	Good	Bad	Readable	Not readable
25	96 %	4%	100%	0%

Overall, the user interface of the application is appreciated. The bottom navigation got a positive response in terms of clicks, reachability and achieving the main task of the application.

4.2 Ease of use

During the evaluation, the users' remarks about the simplicity of the application, and the steps to accomplish their targeted tasks were positive. The evaluation was set up in a semi-structured way to avoid the burden of filling a huge questionnaire by the respondents. Therefore, the users were randomly asked about the effectiveness and efficiency [7] of the application.

The overall feedback and responses of the participants show, as depicted in figure 17, that the efficiency and recognition of steps to accomplish the task (medication record and symptoms feedback) is quite high and is rated 100% by 25 participants. The participants highlight that the system is simple and easy to use. The main attractions were about the multiple-choice options for the feedback on daily symptoms. The remarks during the evaluation are like *"the chances of making errors during daily symptoms feedback is minimum because of taping the choice option for each question"*. Furthermore, the users appreciated the notification system. The notification popups remind the user daily symptoms feedback and medication intake to makes users stay connected with the application.

The SYNC button functionality on the main screen was not clear to the participants. This functionality of the SYNC buttons is to send the user data (medication record, symptoms feedback, location data, sensor data) to the Aware server. It was understood for refreshing the sensor data on the main screen.

4.3 Ruuvitag sensor data validation

The application is designed to get the temperature and humidity values along with the signal strength from the Ruuvitag sensor and display the values in real-time to the user. The sensor connectivity and data fetching are tested many times by connecting and disconnecting the Ruuvitag sensor device. The concurrency of sensor data is tested with multiple sensors by connecting multiple sensors at the same time. The application receives data from the sensor with high signal strength. The sensors connect automatically by signal strength values. The request for fetching data from a sensor is made in every 1000 milliseconds. The main screen is updated with the latest data. The size of each record is approximately 48 bytes.

The cross-validation of sensor data is made by comparing the values on both applications, i.e., 'EXTREMA' and the official Ruuvitag workstation application [2]. The values were similar and tested many times at different locations with multiple sensors. The device ID, weather temperature, humidity value, and signal strength are, almost exactly, the same. The following figure 19 shows the sensor data validation.

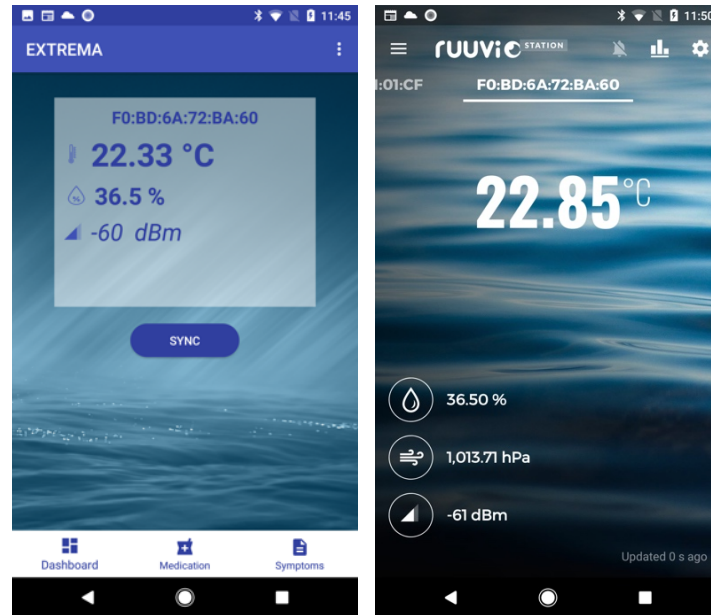


Figure 19. Comparing sensor data on different applications.

4.4 Server data confirmation

The user data is saved in a local database at user mobile. When the user taps the SYNC button on the main screen, the saved data is sent to the online Aware server if the mobile has internet connectivity. The data is saved in the Aware server in a database named 'murad'. The database has several tables such as bluetoothData, IndoorsTag, locationData, participantData and surveyData as shown in the following figure 20.

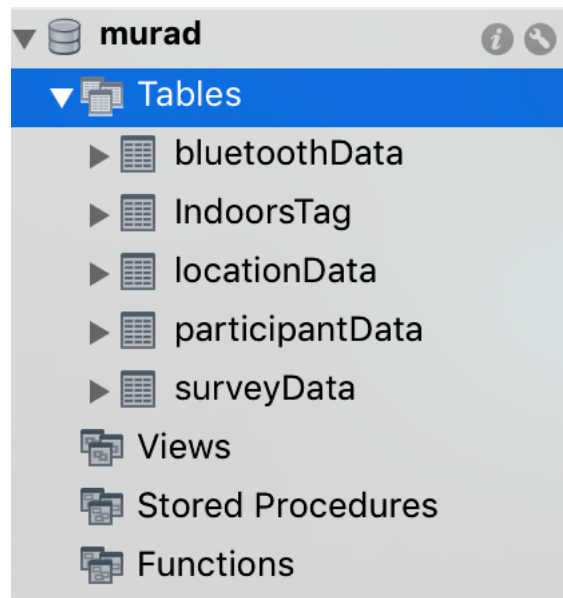
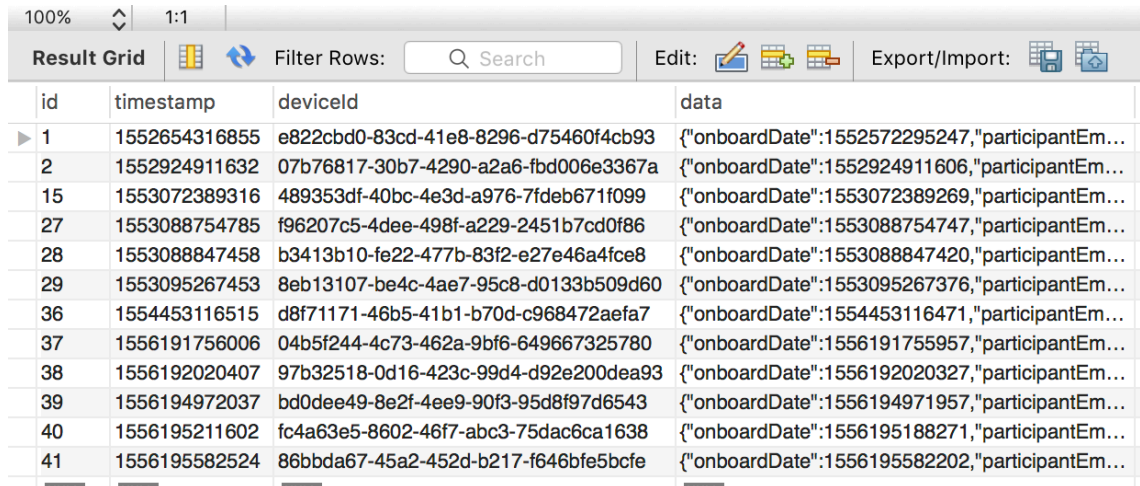


Figure 20. Aware server database 'murad' tables.

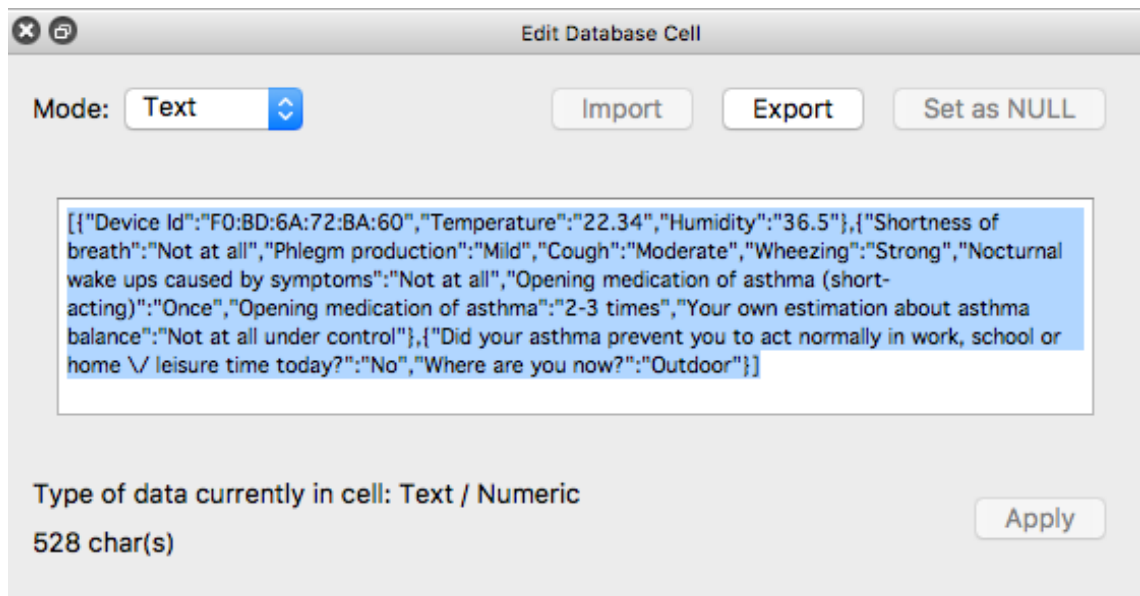
The structure of each table has the same attributes. Each table has an ID, timestamp, device ID and data column. The ID column represents a unique ID. The timestamp column has the timestamp of the user feedback time. The data column has the user

symptoms data, medication record, location data, sensor data, and user information respectively. The following figure 21 shows the data in participantData table. The user data in the data column is in JSON format, as shown in figure 22.



id	timestamp	deviceId	data
1	1552654316855	e822cbd0-83cd-41e8-8296-d75460f4cb93	{"onboardDate":1552572295247,"participantEm...
2	1552924911632	07b76817-30b7-4290-a2a6-fbd006e3367a	{"onboardDate":1552924911606,"participantEm...
15	1553072389316	489353df-40bc-4e3d-a976-7fdeb671f099	{"onboardDate":1553072389269,"participantEm...
27	1553088754785	f96207c5-4dee-498f-a229-2451b7cd0f86	{"onboardDate":1553088754747,"participantEm...
28	1553088847458	b3413b10-fe22-477b-83f2-e27e46a4fce8	{"onboardDate":1553088847420,"participantEm...
29	1553095267453	8eb13107-be4c-4ae7-95c8-d0133b509d60	{"onboardDate":1553095267376,"participantEm...
36	1554453116515	d8f71171-46b5-41b1-b70d-c968472aefa7	{"onboardDate":1554453116471,"participantEm...
37	1556191756006	04b5f244-4c73-462a-9bf6-649667325780	{"onboardDate":1556191755957,"participantEm...
38	1556192020407	97b32518-0d16-423c-99d4-d92e200dea93	{"onboardDate":1556192020327,"participantEm...
39	1556194972037	bd0dee49-8e2f-4ee9-90f3-95d8f97d6543	{"onboardDate":1556194971957,"participantEm...
40	1556195211602	fc4a63e5-8602-46f7-abc3-75dac6ca1638	{"onboardDate":1556195188271,"participantEm...
41	1556195582524	86bbda67-45a2-452d-b217-f646bfe5bcfe	{"onboardDate":1556195582202,"participantEm...

Figure 21. ParticipantData table.



Mode: Text

Import Export Set as NULL

```
[{"Device Id":"F0:BD:6A:72:BA:60","Temperature":"22.34","Humidity":"36.5"},{"Shortness of breath":"Not at all","Phlegm production":"Mild","Cough":"Moderate","Wheezing":"Strong","Nocturnal wake ups caused by symptoms":"Not at all","Opening medication of asthma (short-acting)":"Once","Opening medication of asthma":"2-3 times","Your own estimation about asthma balance":"Not at all under control"},{"Did your asthma prevent you to act normally in work, school or home \\/ leisure time today?":"No","Where are you now?":"Outdoor"}]
```

Type of data currently in cell: Text / Numeric

528 char(s)

Apply

Figure 22. User symptoms data JSON format in the data column.

4.5 Components testing

Each component of the application is tested in several conditions and the performance of every component is measured after the iterative development of the application. The following components are tested during the test run.

4.5.1 Login and registration testing

The purpose of this testing was to ensure that the user is registered to the system. When the user launches the application and performs some activities, the user data is stored in a local database. The user has a unique ID. It is also tested that the user data is saved

according to the user's unique ID (UUID) along with other information. This unique ID will help the researchers to identify the users. Figure 23 shows the user registration table and figure 24 shows the user data in the registration table.

Registration_Table			CREATE TABLE Registration_Table(Name TEXT, DateOfBirth TEXT, Email TEXT, Password TEXT ,Uuid TEXT, Timestamp REAL)
Name	TEXT		'Name' TEXT
DateOfBirth	TEXT		'DateOfBirth' TEXT
Email	TEXT		'Email' TEXT
Password	TEXT		'Password' TEXT
Uuid	TEXT		'Uuid' TEXT
Timestamp	REAL		'Timestamp' REAL

Figure 23. User registration table.

The following figure shows the user data in the registration table.

	Name	DateOfBirth	Email	Password	Uuid	Timestamp
1	murad	3-1-2019	muradahmad08@gmail.com	1234567	5425ca5d-cb1f-465e-8cbb-22058850f9b1	1556534206473.0

Figure 24. User registration data.

4.5.2 User Interface text and clicks testing

The user interface of each component is tested to check whether the text is correct, and the clicks are working. Saving the user data and information were checked in the process. The buttons and text are in a proper position and working according to the functionality. The following figure 25 shows the clicks of the buttons.

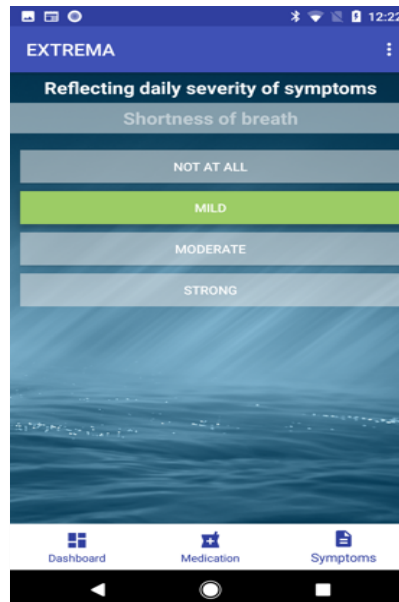


Figure 25. Buttons clicks.

4.5.3 Location data testing

The location data is tested in multiple places, indoor and outdoor. The number of satellites shows the user indoor or outdoor positioning. The following figure shows the user location data. The number of satellites is 0 which means that the user is inside a building. The accuracy shows that the user actual position accuracy is 25 meters approximately, similarly, the altitude is 43 meter.

	Location	Times
88	{"latitude":65.0578728,"longitude":25.4698084,"accuracy":25.868000030517578,"altitude":43.400001525878906,"provider":"fused","speed":0,"bearing":0,"satellites":0,"isIndoor":true}	1556

Figure 26. Indoor location data.

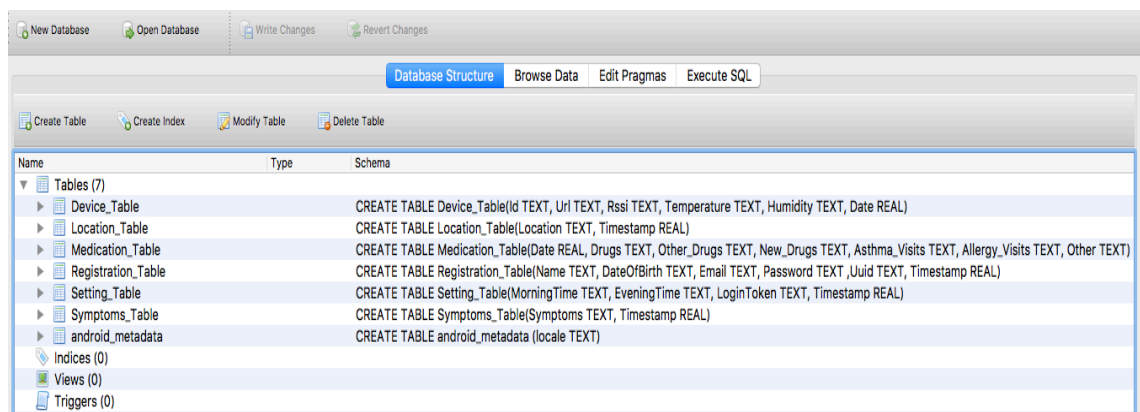
The following figure shows the user location and the number of satellites are 49 which means that the user is outdoor.

	Location	Times
204	{"latitude":65.0578791,"longitude":25.4691641,"accuracy":26.2450008392334,"altitude":43.400001525878906,"provider":"fused","speed":0,"bearing":0,"satellites":49,"isIndoor":false}	1556

Figure 27. Outdoor location data.

4.5.4 Local database testing

The user data is saved in a database.db file in the following folders hierarchy: /Users/morahmad/Documents/AndroidStudio/DeviceExplorer/google-pixel-FA77P0301032/data/data/com.ubicomp.murahmad.asthma/databases/database.db
The size of database.db file is 1.2 megabytes. The database contains 7 tables. Each table has the user data stored in it. The structure of the database is shown in figure 28.



Name	Type	Schema
▼ Tables (7)		
Device_Table		CREATE TABLE Device_Table(Id TEXT, Url TEXT, Rssi TEXT, Temperature TEXT, Humidity TEXT, Date REAL)
Location_Table		CREATE TABLE Location_Table(Location TEXT, Timestamp REAL)
Medication_Table		CREATE TABLE Medication_Table(Date REAL, Drugs TEXT, Other_Drugs TEXT, New_Drugs TEXT, Asthma_Visits TEXT, Allergy_Visits TEXT, Other TEXT)
Registration_Table		CREATE TABLE Registration_Table(Name TEXT, DateOfBirth TEXT, Email TEXT, Password TEXT, Uuid TEXT, Timestamp REAL)
Setting_Table		CREATE TABLE Setting_Table(MorningTime TEXT, EveningTime TEXT, LoginToken TEXT, Timestamp REAL)
Symptoms_Table		CREATE TABLE Symptoms_Table(Symptoms TEXT, Timestamp REAL)
android_metadata		CREATE TABLE android_metadata (locale TEXT)
Indices (0)		
Views (0)		
Triggers (0)		

Figure 28. Local database structure.

A simple query is executed to test the data of the Symptoms_Table. The following figure 29 shows a query and the result of the query. The table has seven rows with daily symptoms data records. Each row has the detail of daily symptoms data as shown in the following figure 29.

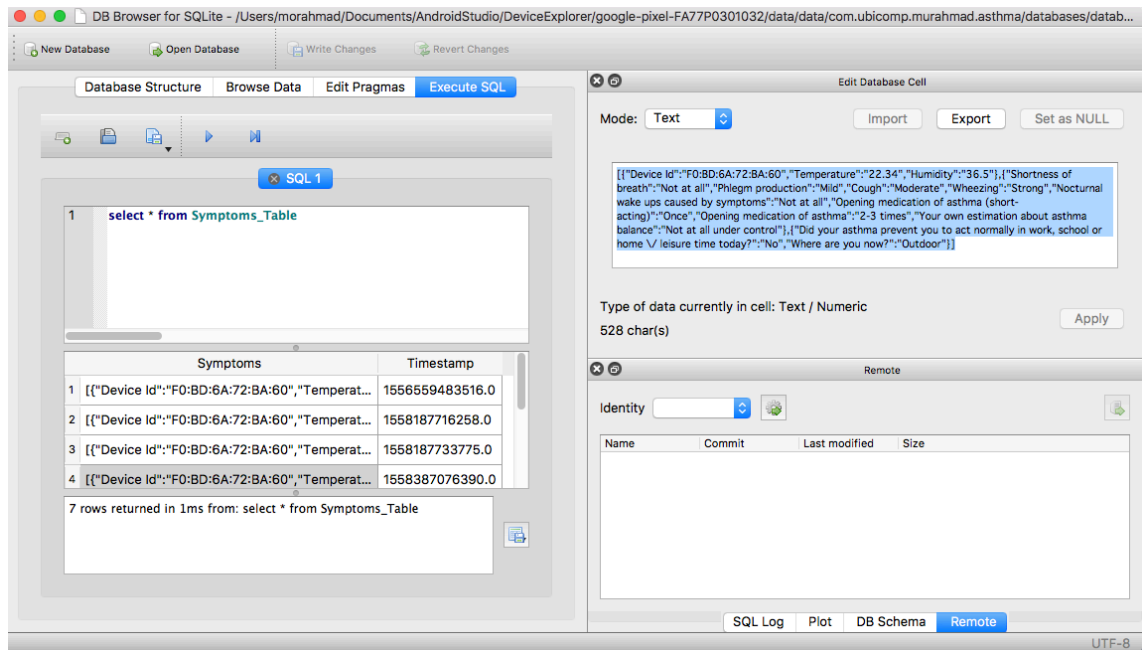
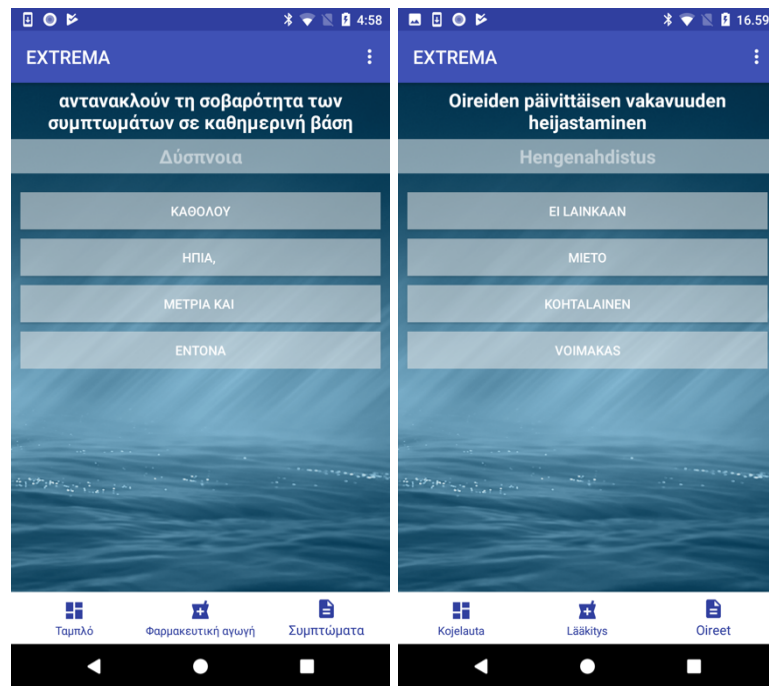


Figure 29. Query and details of single row data.

The volume of the data depends on the number of records stored in each table. Therefore, the size of the database file is according to the user data. For example, in this case, the size of one symptoms record is 528 bytes approximately. If we calculate the number of rows with the size of one record, the total size is approximately 3696 bytes of data for the symptoms table.

4.5.5 Language testing

The application is developed with three languages, i.e., English, Finnish and Greek language. The application is translated into one of these languages based on the user location. The following figure 30 shows the application in Greek and Finish.



a) Greek language interface b) Finnish Language interface

Figure 30: Language option of the application.

5. DISCUSSION

Mobile phones, wearable devices, and external sensors are used in the health sector to improve the quality of health care. Mobile and wearable devices passively monitor the health activities of the users with effective engagements [3] and collect user data accurately in real-time. Smartphones are developed with technological capabilities to connect to external sensors and receive data from a diverse set of sensors. Hence, mobile applications are developed for specified contexts to receive data from sensors, process the received data, and present the necessary contextual information to users [30], [31], [32].

This thesis work is following the research in the field of mHealth and is focused on providing an application for the assessment of the effects of climate change on asthma patients. The application aimed to help both individual users and researchers to efficiently gather self-reported symptoms data, and medication record according to weather conditions and user location.

As discussed in the related work in Chapter 2, there are many applications available in the market. The applications with a high number of downloads and user ratings are mentioned in this work for comparison purposes, and to point out the novelty of this work. The previous solutions have the following features:

- Tracking of asthma symptoms
- Medication reminder
- Peak flow values
- Visual representation

Peak flow [17] has an additional feature about the pollen flight information. The limitation of previous work based on user's reviews and ratings:

- AsthmaMd [15] is complicated, as well as the user interface is not interactive and user-friendly. The notification system is not properly working. The application hangs during saving the medication form, and the data syncing is not properly working.
- The Asthma Tracker [16] application is using google fit API to count the user steps. The user cannot use it without google fit API. Furthermore, the user cannot export medication and symptoms record to doctors.
- The previous solutions track and monitor patient's data at the user mobile phone only.

Similarly, in the previous work, the patient's data is not available remotely to doctors and professional researchers. The data can be forwarded to doctors by exporting it manually. Secondly, the saved patient's data in user mobile can be risky and could be lost due to many reasons including but not limited to loss of the mobile device, malfunctions in a mobile device or accidental reset, etc.

The previous solutions have a major limitation in terms of collecting weather data without the user location to measure the effects of climate change on asthma patients. Therefore, the current work monitors and tracks asthma patients in real time with respect to location and weather data to assess the effects of climate change on patients. The 'EXTREMA' application developed in this thesis, is an intelligent android mobile application targeted towards patient's in various scenarios, e.g., indoor activities, outdoor activities. The 'EXTREMA' application receives input from a patient including daily medication intake and symptoms feedback along with weather data from the external smart weather sensor,

i.e., Ruuvitag [27]. The ‘EXTREMA’ application collects location data from the GPS (Global Positioning System) location sensor in the smartphone along with a number of satellites used. The number of satellites indicates user positioning. Furthermore, the application is developed with the notification system and has the option of setting up the notification time for medication intake and symptoms feedback according to the user’s preferences. The application is developed with the options of three languages, i.e., English, Finnish and Greek. The application will automatically adopt the choice of the user mobile language based on the location of the user. The data of each patient is saved in a user mobile phone and then sent an online server. The collected data is communicated over the Internet with a remote server (called Aware) accessible by research/medical professionals who are in charge of the remote monitoring of the patients. The patient’s data is in JSON format [28], which is easy to understand and read.

The user interface of the application is kept simple to achieve the maximum goal of collecting patient’s data. The user interface of the application is evaluated empirically [34] using usability heuristics [8], [9]. The users were randomly asked about the effectiveness and efficiency of the application. The overall feedback and responses of the participants are shown in figure 17 in section 4.1. The results reveal that the efficiency and recognition of steps to accomplish the task (medication record and symptoms feedback) is quite high (numerically 100% by 25 participants). The participants argue that the system is simple and easy to use. The arguments were about the multiple-choice options for daily symptoms feedback. The remarks during the evaluation “*The chances of making errors during daily symptoms feedback is minimum because of taping the choice option for each question*”. Furthermore, the notification system was appreciated by the users to remind the users on the desired time to give daily feedback. Moreover, limitations of this work pointed out by the participants include the SYNC button and medication list. The functionality of the SYNC button was not clear to the participants. The functionality of the SYNC buttons is to send the user data (medication record, symptoms feedback, location data, sensor data) to the aware server. It was misunderstood for refreshing the sensor data on the main screen. Secondly, the medication form was argued to be improved by providing a list of medications.

The application is developed with the most important features and can be extended with new features. The graphical representation of the user data and a dashboard to display the patient data in categories based on weekly reports or monthly reports are the important features to be developed. Secondly, future work includes a peak flow meter to measure the peak flow values of asthma patients. The peak flow meter should be introduced as gamification. The fundamental goal of gamification is to create systems that are more fun and more engaging by gamifying them [35], [36]. However, the current system already provides all the necessary functions needed for properly monitoring the health of asthma patients, and timely providing them the healthcare.

6. CONCLUSION

The thesis work is following the research in the field of mHealth and tracking the climate change effects on patients of asthma. The increased risks of climate change necessitate protective measures in several dimensions. The main threats of climate change directly impacting human lives can be recognized by bringing technology into use. One such use is recognized, and the solution has been developed and evaluated in this thesis. A mobile application, called 'EXTREMA', has been developed and studied. The main target of the application is measuring the effects of climate change on asthma patients and then providing efficient healthcare.

The application collects user information, stores it in the online server, using the Aware framework, and makes the information readily available online for research purposes and to professionals in the field of medical and health sciences. The application records daily symptoms, patient's medication records, and patient's location along with weather data. The usability of the application has been tested through real-time usage study. Users were asked to use the application and answer an easily understandable questionnaire. The users found the application highly user-friendly, easily understandable and its features easily recognizable.

The application can be improved with future work by adding a visual representation of data and peak flow meter to measure the peak flow values of the asthma patients. The peak flow meter could be introduced as gamification. Nonetheless, the application provides enough framework to start using it in real-time to help asthma patients.

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8. APPENDICES

Appendix 1 User interface evaluation form and discussion questions

Appendix 2 Requirements of the application

Appendix 1: User interface evaluation form

The following form was given to the participants to express their views regarding the user interface of the application.

Application UI Survey

Application UI Survey

Contact: muradahmad08@gmail.com

* Required

1. **Visibility of System Status ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good
2. **User control and freedom ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good
3. **Consistency and standards ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good
4. **Error prevention ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good
5. **Recognition rather than recall ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good
6. **Flexibility and efficiency of use ***
Mark only one oval.
☐ Poor
☐ Satisfactory
☐ Good

<https://www.scribd.com/document/401414848/Questionnaire-UI-Survey-Form>

1/1

[illegible]

Discussions and questions

Results

Questions:

- ① The application is Complex.
- ② The system is easy to use.
- ③ The system is easily understandable
- ④ I think that I would need support to use the system.
- ⑤ The questions of feedback are easy to reply.
- ⑥ The questions of symptoms feedback are complicated.
- ⑦ Medication form filling is complicated.
- ⑧ The notification timing option is easy
Additional question
- ⑨ Ruuvitag device is easy to get purchased
- ⑩ Weather data without Ruuvitag device
- ⑪ Did you find the application or any part difficult to understand or use.

DIARY (Page 1)

Date: . . . 2019

SYMPTOMS

Options reflecting daily severity of symptoms: 1= Not at all, 2 = Mild, 3 = Moderate and 4 = Strong.

Shortness of breath ☐1 ☐2 ☐3 ☐4 Phlegm production ☐1 ☐2 ☐3 ☐4
 Cough ☐1 ☐2 ☐3 ☐4 Wheezing ☐1 ☐2 ☐3 ☐4

Options reflecting daily frequency of symptoms or daily frequency of medication usage: 1= Not at all, 2 = Once, 3 = 2-3 times and 4 = four times or more.

Nocturnal wake ups caused by symptoms ☐1 ☐2 ☐3 ☐4 *7h → 9h ← Morning*Opening medication of asthma (short-acting) ☐1 ☐2 ☐3 ☐4Opening medication of asthma ☐1 ☐2 ☐3 ☐4

Your own estimation about asthma balance:

☐1 Good ☐2 More or less under control
☐3 Poorly under control ☐4 Not at all under control

Did your asthma prevent you to act normally in work, school or home / leisure time today?

☐No ☐Yes*INDOOR
OUTDOOR*

June 6, 2018 REACT

REACT Daily Diary for Asthma: Translation for Relevant Parts

INSTRUCTIONS for the completion of symptom and medication diary

Attached you will find symptom and medication diary. Diary is meant for daily fill.

1. Mark date for every pages of diary.
2. Answer for every questions related to symptoms. Record daily symptoms.
3. Record daily information about the usage of medication.

PERSONAL DETAILS

Name: _____

ID: _____

CURRENT ASTHMA AND ALLERGY MEDICATION AND DOSE

Opening medication of
asthma: _____The therapeutic drug of asthma (complex products
also): _____Other asthma
medication: _____

CHANGES IN MEDICATION AND NEW DOSE:

COMMON COLDS / DOCTOR VISITS DUE TO ASTHMA

COMMON COLDS / DOCTOR VISITS DUE TO ALLERGY

OTHER CONSIDERATIONS
